

WDM for Military Platforms Workshop
April 18-19, 2000

WDM Sensor Networks for Military Platforms

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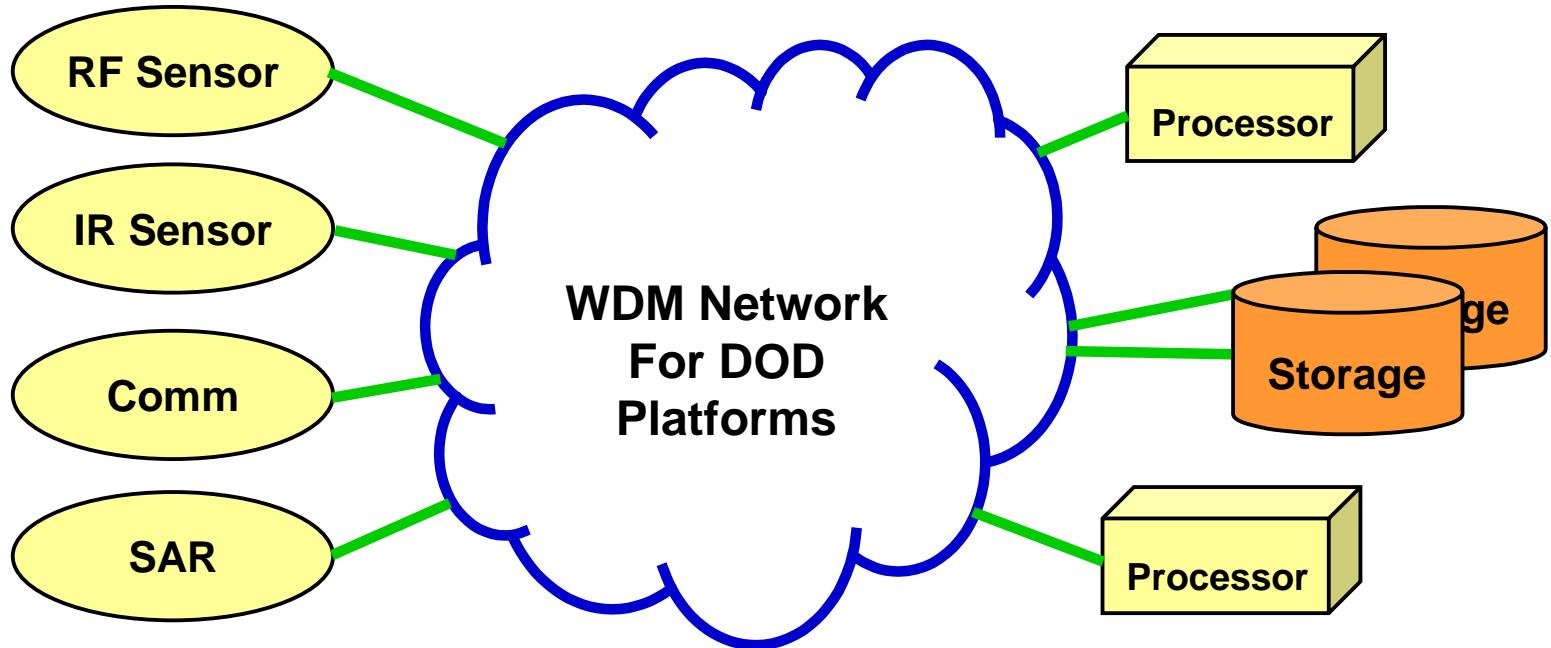
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OUTLINE

- **The emerging Optical Transport Networking (OTN) for telecom**
- **WDM sensor networks**
- **New components required**
- **New functions enabled by the network**

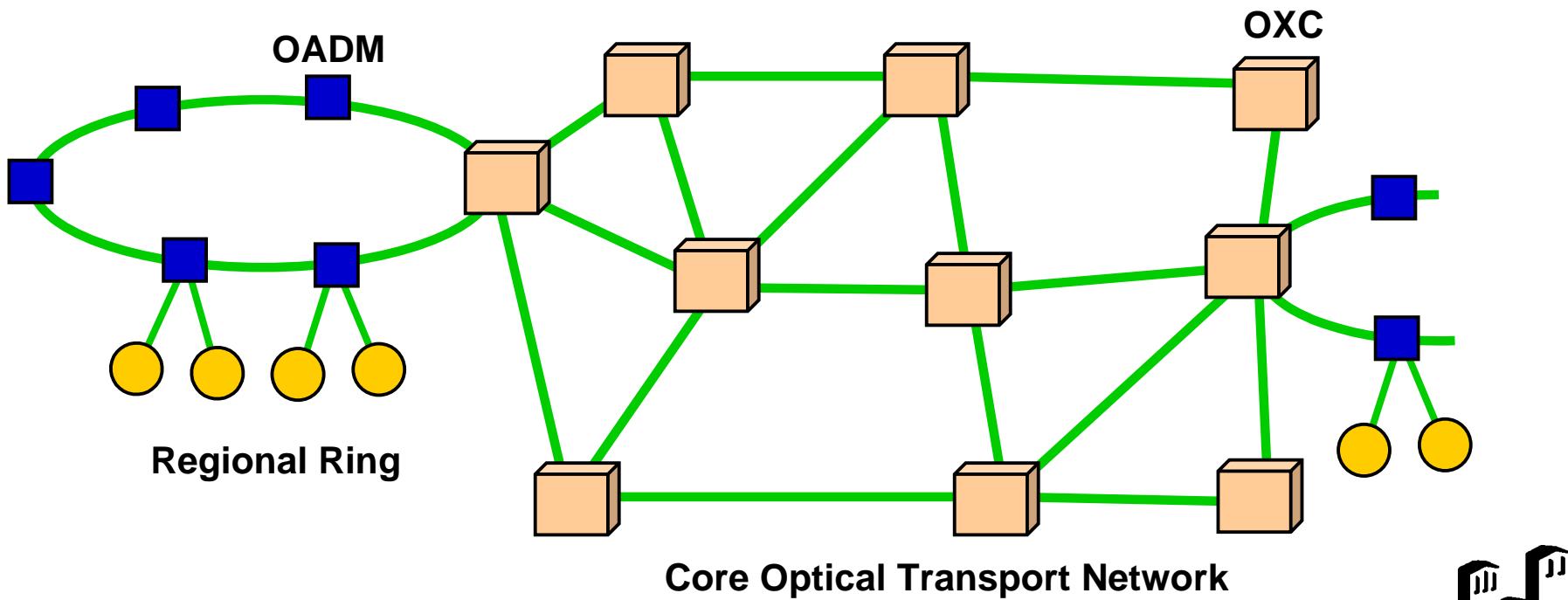
Ideal Sensor Networks for DOD Platforms



- Mixed RF/digital/analog signals
- Distributed sensors in all locations
- Connectivity (more than point-to-point)
- High survivability, fault tolerant
- Dynamic reconfigurable, wide instantaneous bandwidth

Telecom Optical Transport Networking

- WDM is quickly evolving from **point-to-point capacity expansion** to scalable and robust **optical transport networking (OTN)**
- Catering to an expanding variety of client signals with equally varied service requirement

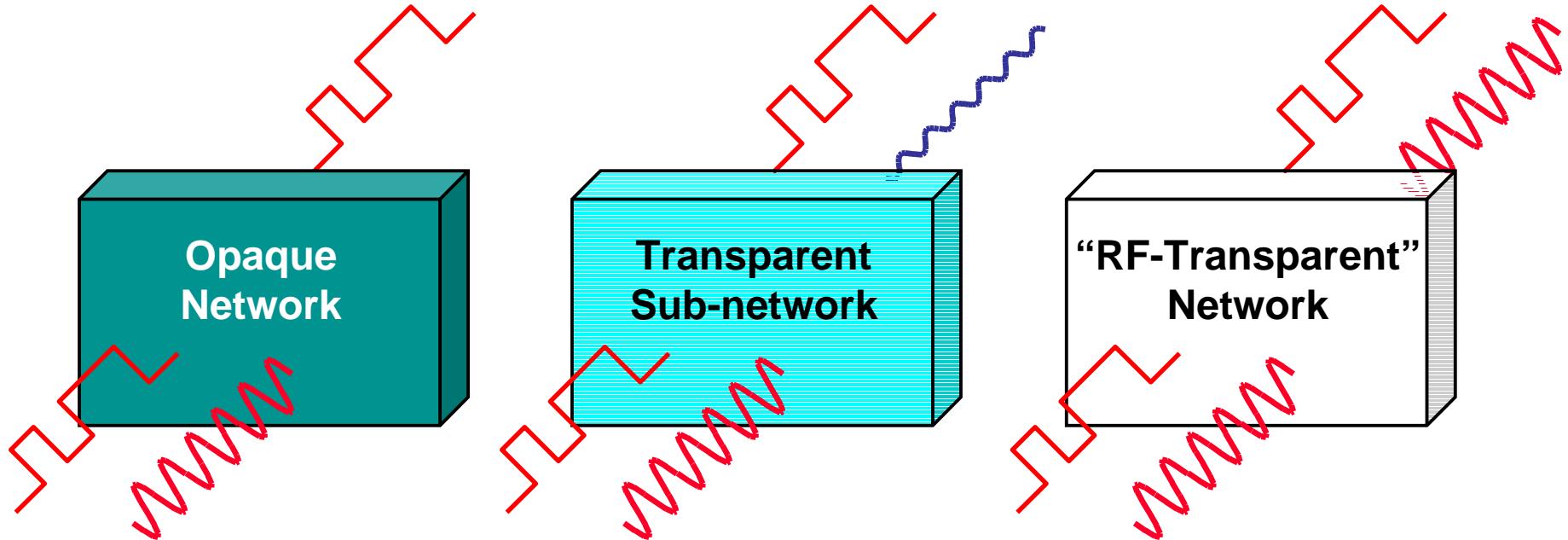


The Issue of Optical Transparency

- Early visions of “All-Optical” Transport Networking
 - Any signal (digital or analog)
 - Anywhere
 - Anytime
- “Idealized” vision tempered by practical constraints –
analog network engineering → “Opaque networks”
 - “Optoelectronics” (usually with 3R) required to mitigate analog noise accumulation and maintain the network
- Practical vision of OTN
 - Optically transparent sub-networks (islands) bounded by feature-enhanced optoelectronics
 - Size and capability of the optically transparent sub-network grows as technology and standards matures

Adapted from: P. Bonenfant, “Optical Networking Standards,” OFC 2000 Tutorial

Granularity of “Transparency”

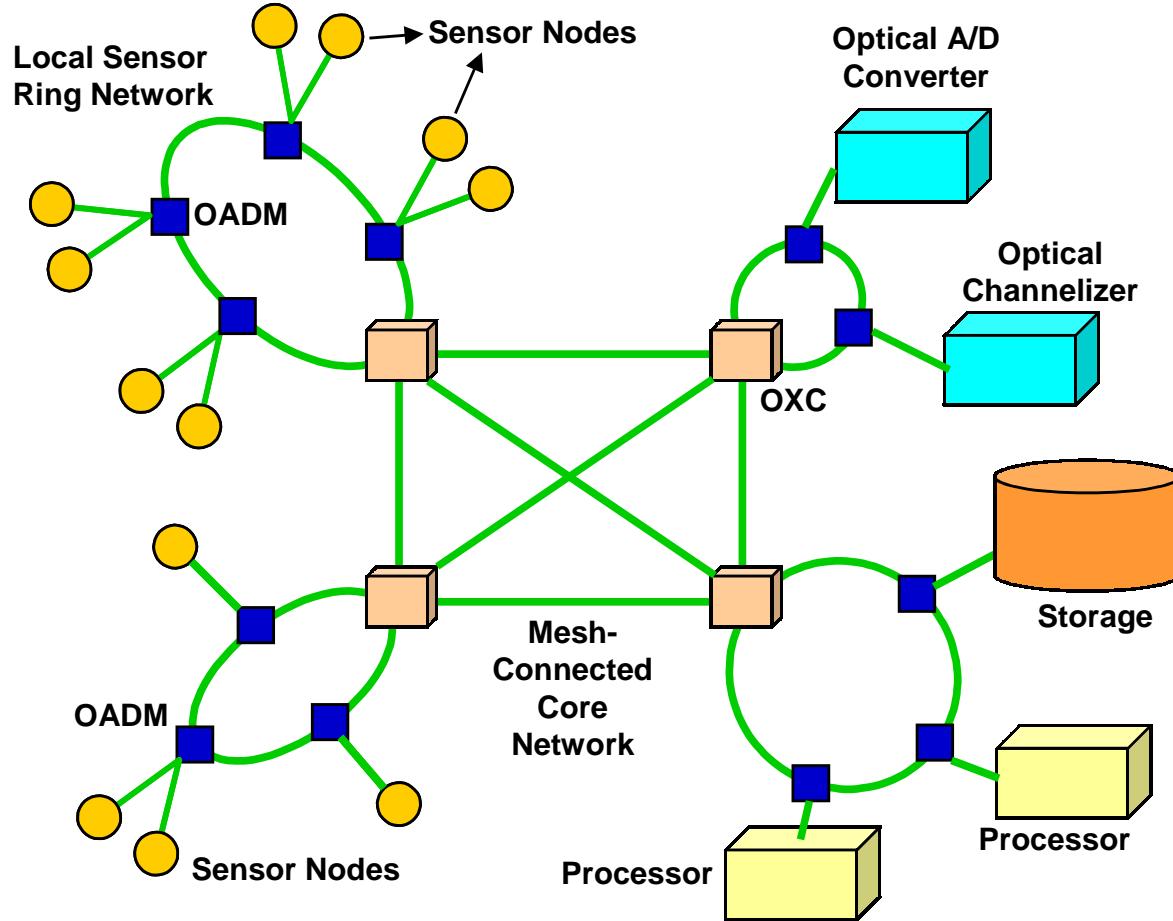


- Multi-vendor interoperability
- No cumulative impairments (noise, nonlinearity)

- Provisioning and restoration at wavelength level
- RF signal integrity not guaranteed

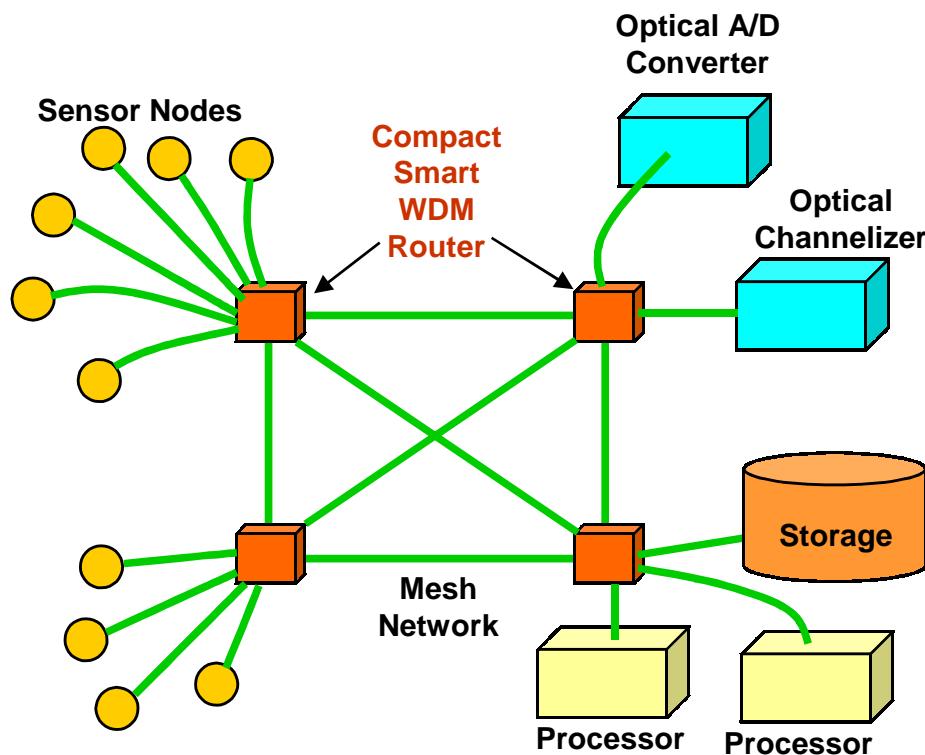
- Support mixed RF/digital signals
- Need “RF-compliant” WDM components

WDM Integrated Sensor Network



- Highly survivable
 - Built-in protection and restoration
- Dynamically reconfigurable
- Provisioning at wavelength level (**Bandwidth on demand**)
- Support large number of nodes
- **“Future-proof”**
 - Add more sensors
 - Add optical front-end preprocessors
 - Increase RF frequency
- **Pay as you grow**
 - Add more wavelengths when needed

OXC for WDM Sensor Network

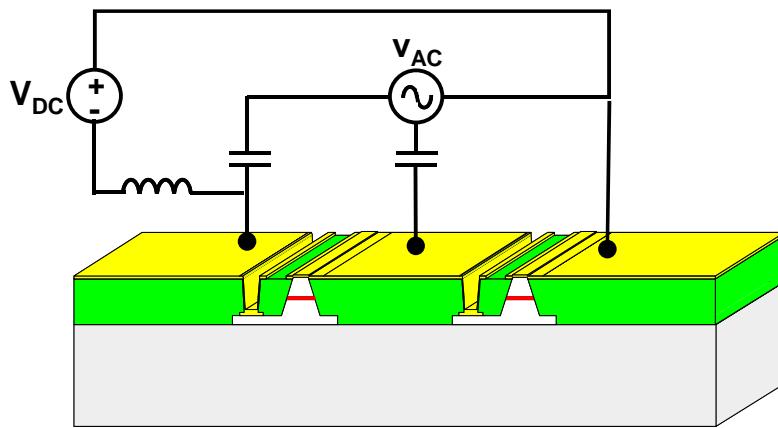
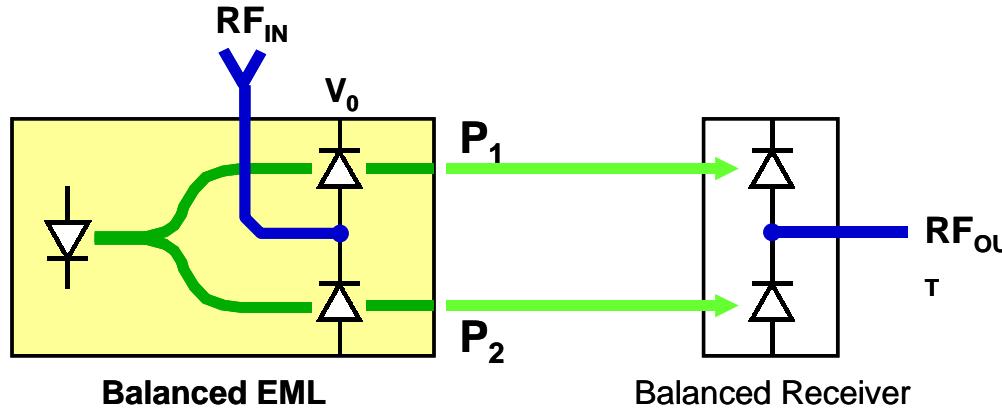


- Need much more compact OXC
 - Telecom OXC too big in size, weight, power, and capacity
- What can we do without?
 - Probably don't need wavelength conversion (?)
 - Use wavelength-selective cross connect (WSXC)
- Combine WSXC and OADM
 - Smart WDM Router

RF-Compliant Components

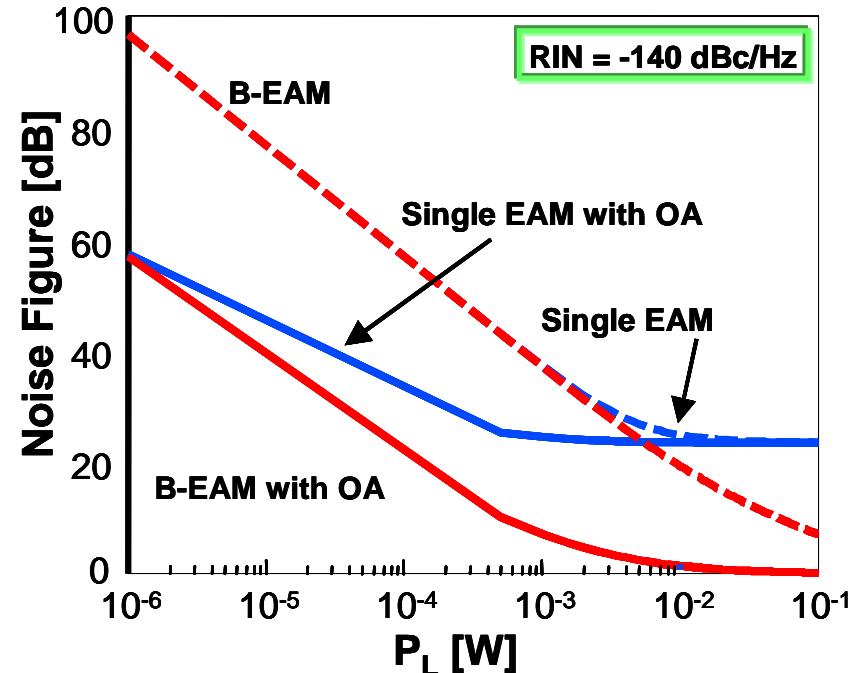
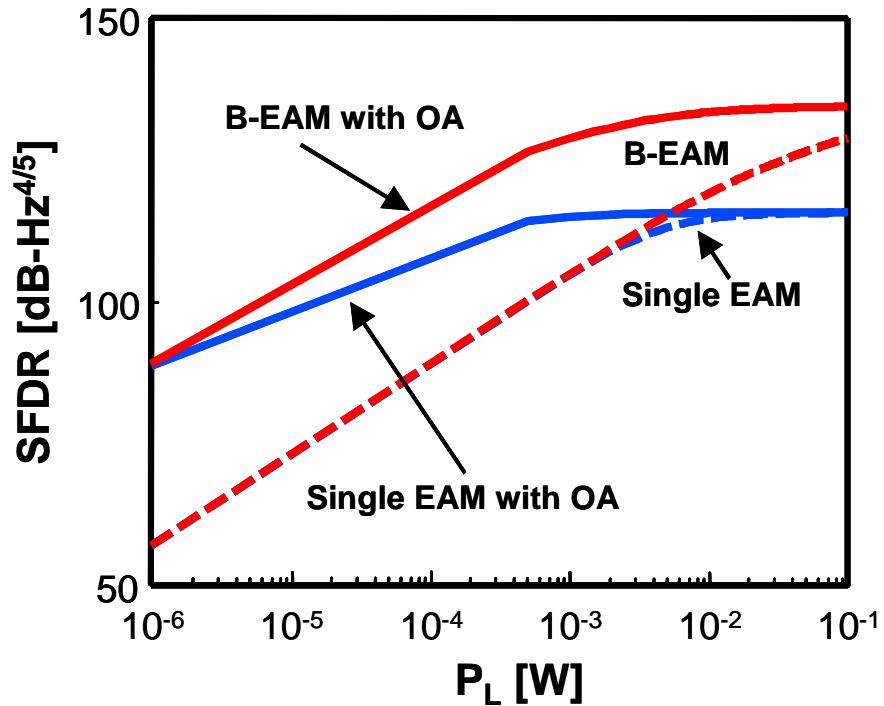
- WDM components with < -40 dB optical isolation
- Flat passband response
- Many RF-compliant optoelectronic components are being developed by RFLICS
- Balanced EA modulator with high linearity and low noise

Balanced EA Modulator (BEAM) for “RF-Transparent” WDM Networks



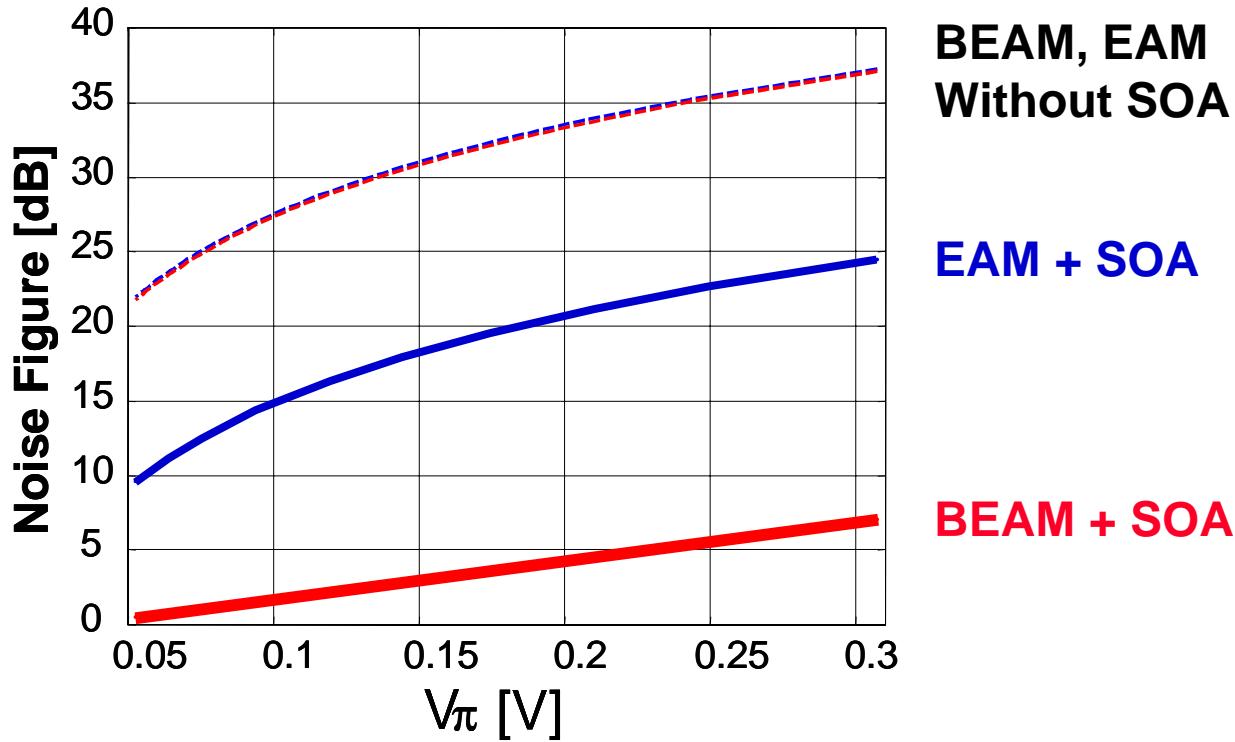
- Complementary output at **all bias voltages**
- BEAM balanced link:
 - All even order distortions cancelled
 - 3rd order intermod nulled
 - RIN cancelled
 - Common ASE of SOA suppressed
- High fidelity link achieved with telecom-grade lasers and modulators
- Ideal for mixed mode (digital + RF) WDM networks

Calculated Spurious-Free Dynamic Range and Noise Figure of BEAM



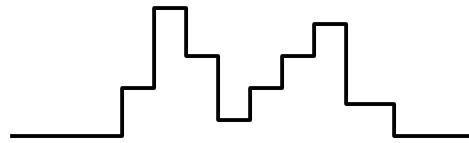
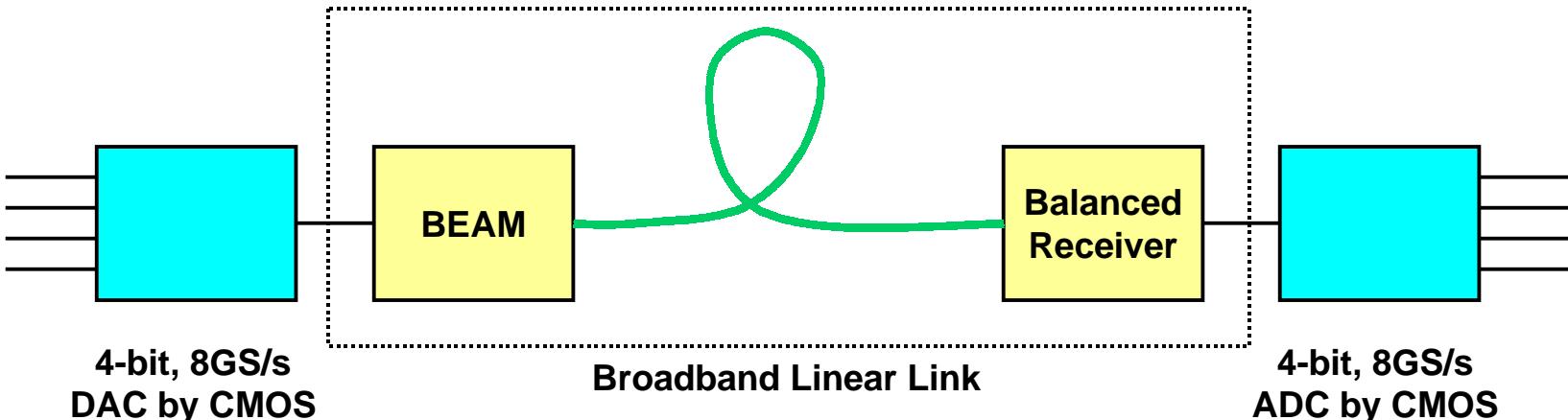
High SFDR and low NF can be achieved at moderate laser power and RIN

Comparison of BEAM and EAM

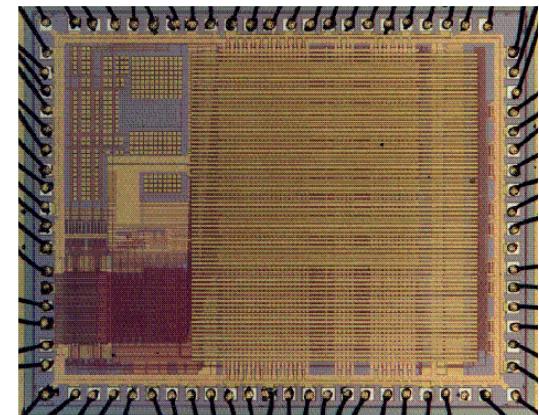


- Noise Figure of BEAM is lower than EAM with 5x lower V_π

Ultra-High Speed Link using CMOS Multi-Level Tx/Rx Chips

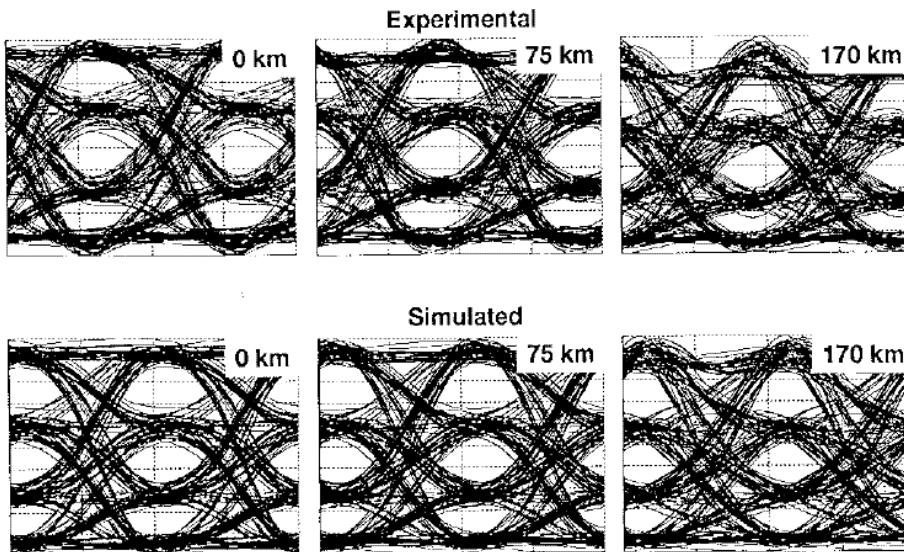


- 30 Gbps transmission by combining linear link with high speed CMOS DAC/ADC
- High spectral efficiency ($>> 1$ bit/Hz)
- Prof. Ken Yang (UCLA), leader in high speed CMOS Tx/Rx design



0.25 μ m CMOS
Prof. Ken Yang (UCLA)

Multi-Level Signaling Digital Transmission



- **M-ary signaling**
 - Reduced bandwidth (bandwidth \sim symbol rate)
 - Increased spectral efficiency ($>> 1 \text{ b/sec/Hz}$)
 - Resistant to dispersion
 - 40 Gbit/s over 35 km standard single mode fiber demonstrated by Alcatel
- **For large M**
 - Need network with large SFDM
 - Need more optical power

- Walklin, S.; Conradi, J. "Multilevel signaling for increasing the reach of 10 Gb/s lightwave systems. IEEE Journal of Lightwave Technology, vol.17, p.2235-48, 1999.
- Wedding, et al. (Alcatel), "40 Gbit/s quaternary dispersion supported transmission over 31 km standard single mode fiber without optical dispersion compensation," ECOC '98, p.523.

SUMMARY

- “RF-transparent” WDM network for sensor networks for military platforms
- Compact Smart WDM Router
- Balanced electro-absorption modulator (BEAM) for mixed RF/digital signals
- Multi-level signaling for possible 40 Gbit/sec WDM in CMOS